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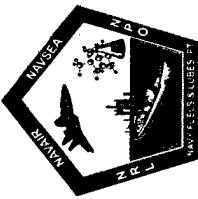


Teaming To Support The Fleet

EVALUATION OF THERMAL STABILITY IMPROVING ADDITIVES FOR JET FUEL IN BOTH LAMINAR AND TURBULENT FLOW TEST UNITS

John E. Colbert & Clarence J. Nowack
U.S. Naval Air Systems Command
Patuxent River, MD
27 September 2000

BACKGROUND



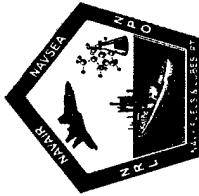
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- (1) New test units are being developed to quantify deposits as an improvement over the JFTOT.
- (2) These units (quantitative), as stand now, are very useful in evaluating the effects of additives on a laboratory scale.
- (3) Scientific community questions the validity of laminar results when aircraft fuel systems are in the turbulent flow regime.
- (4) The purpose of this test program is evaluate the effectiveness of additives in two (2) different test devices - one laminar and the other in the turbulent flow regime.

PEER REVIEW

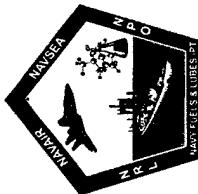
OBJECTIVES

- (1) Determine the sensitivity of two (2) laboratory test units to measure the effectiveness of three (3) different additives in three (3) different types of JP-5.



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EXPERIMENTAL

1. Test Unit Specifications:

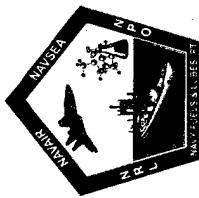
SS The Dimensions

Test Unit ID	Effective Heated Length (inches)	Flowrate (mL/min)	Pre-Heater Exit Temp (°C)	Main Heater Exit Temp (°C)	System Pressure (unitless)	Test Duration (hours)	Tube Exit Filter
Laminar (STR)	0.103 (0.2616 cm)	5 (12.7 cm)	10	121	191	200	500
Turbulent (HiReTS)	0.01 (0.0254 cm)	53125 (13.493 cm)	35	N/A	290	13,000	500 Variable ⁽¹⁾

NOTES.

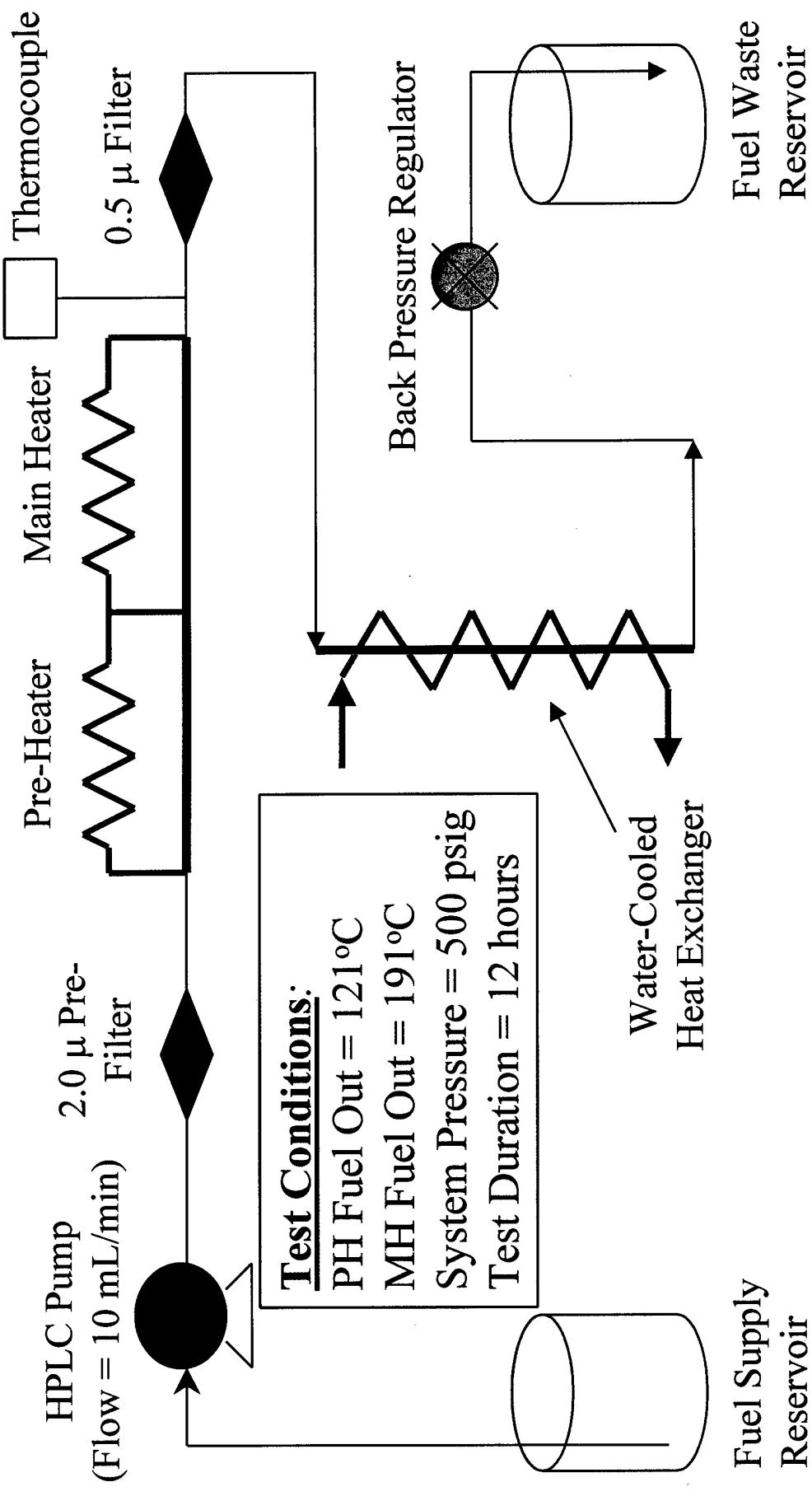
(1) Run HiReTS until a HiReTS No. ≥ 1000 is achieved (capillary failure condition).

EXPERIMENTAL (Cont.)



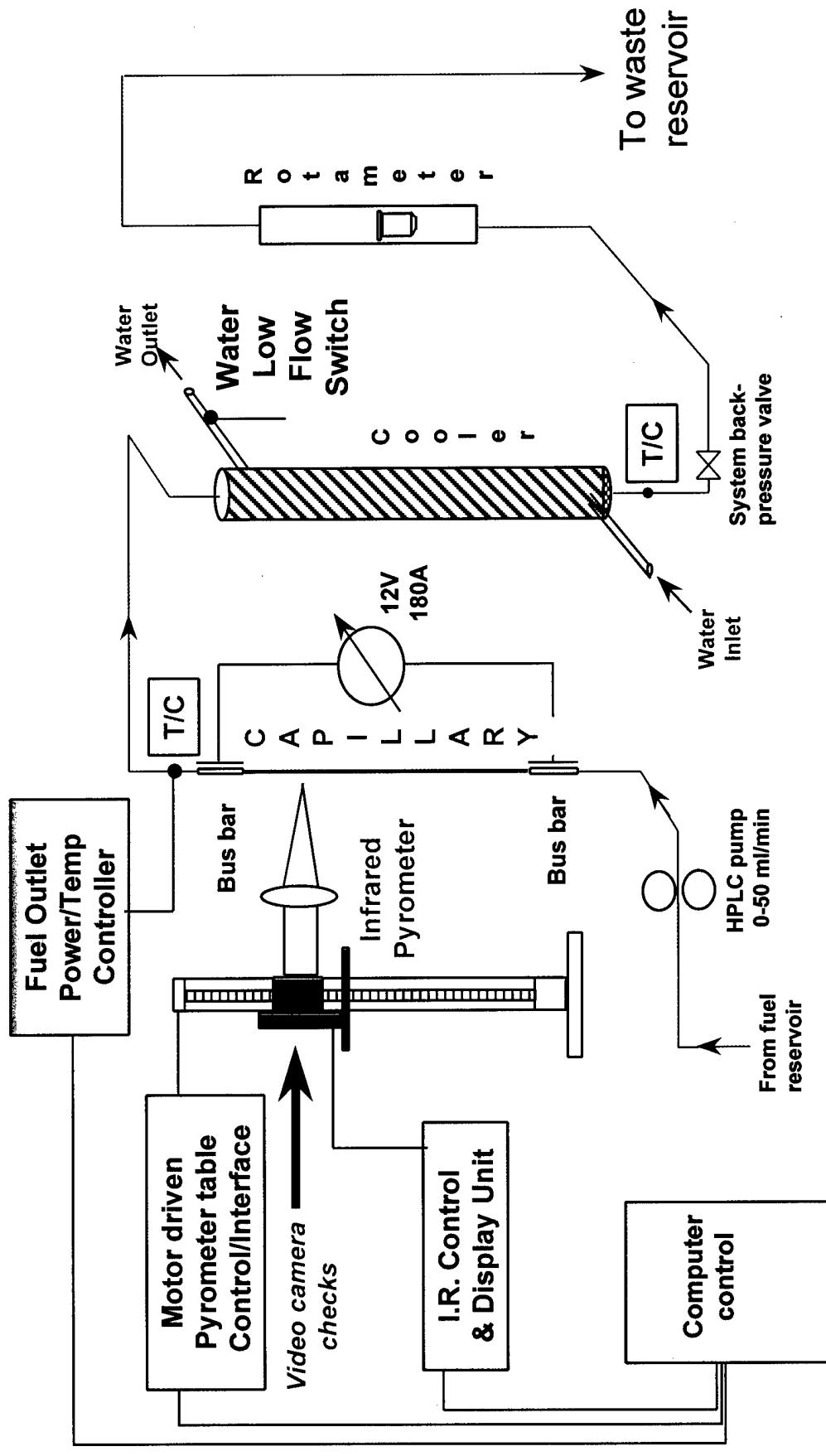
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2a. Test Units (Laminar) - Single Tube Reactor:



EXPERIMENTAL (Cont.)

2b. Test Units (Turbulent) - HiReTS:



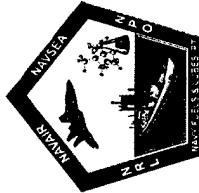


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EXPERIMENTAL (Cont.)

3. Fuels (3 JP-5s):

- a. ***Red Hill Tank 4*** - Shipped from Hawaii and refined by ARCO. An unusual JP-5 due to nitrogen content of 60 ppb which caused the JFTOT to fail with a BPT = 255°C.
- b. ***Tank 17/19*** - a typical JP-5 with a JFTOT BPT = 272°C originating from U.S. Navy facility at Trenton, NJ. Subsequently shipped to Patuxent River, MD for in-house testing.
- c. ***Tank 20/22*** - A JP-5 containing 50 ppb copper, which is typical of a JP-5 stored on air-capable ships containing copper piping. JFTOT BPT = 265°C.



EXPERIMENTAL (Cont.)

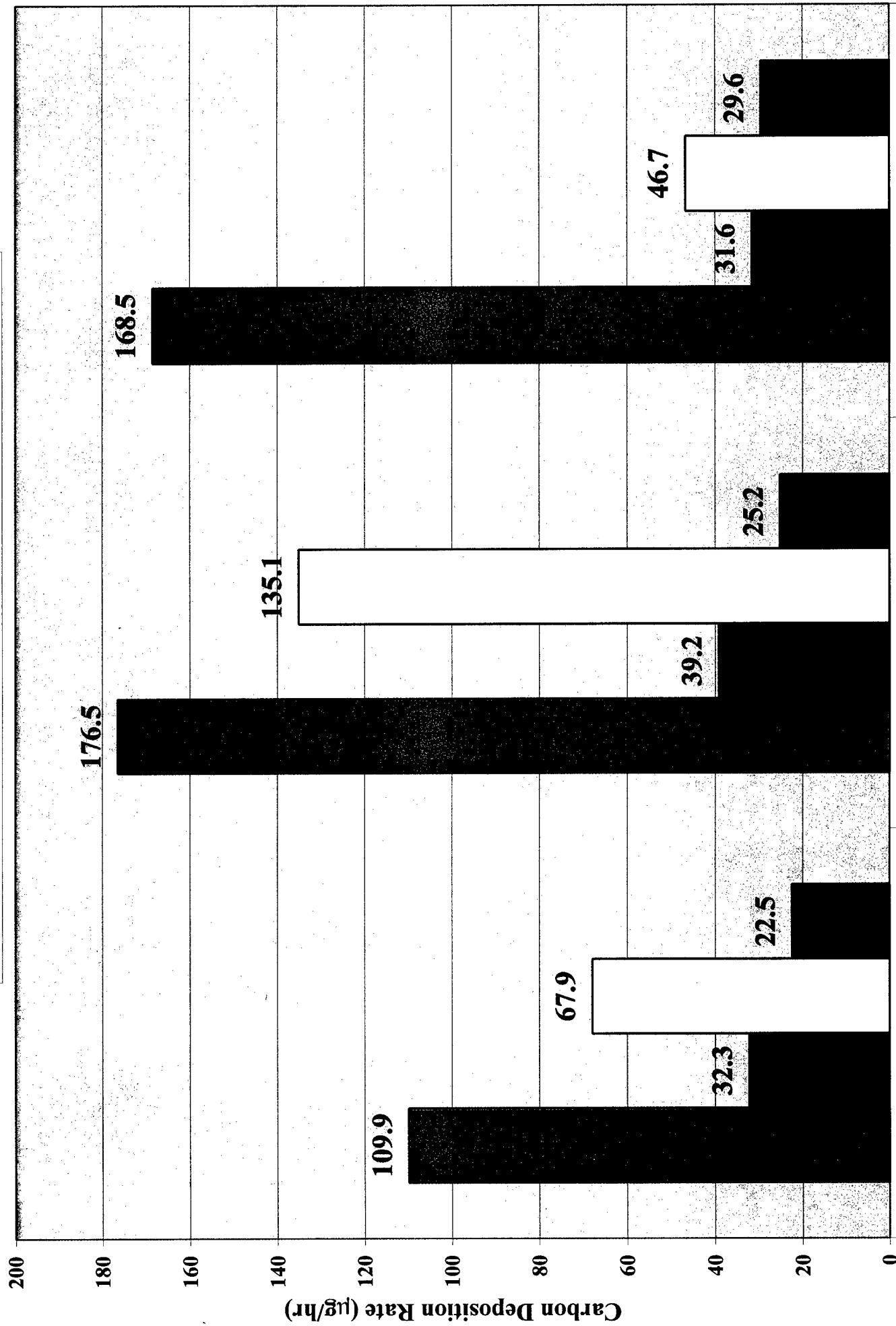
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4. Thermal Stability Improving Additives (TSIAs):

- a. **MDA** - N,N-disalicylidene 1,2-propane diamine. This is a chelate type of compound approved for use in jet fuel used to suppress the catalytic activity of soluble copper. The maximum allowable dosage is 5.8 mg/L.
- b. **Betz 8Q406** - a proprietary formulation consisting of a detergent/dispersant and a butylated hydroxytoluene contained in a hydrocarbon carrier. The recommended dosage is 125 ppm (v/v).
- c. **Betz 8Q462** - this additive is the same as 8Q406 except it contains 2 mg/L MDA. It is used at a concentration of 256 ppm (v/v).

Single Tube Reactor - Total Surface Deposition

■ Neat ■ + 5.8 mg/L MDA □ + 125 ppm Betz 8Q406 ■ + 256 ppm Betz 8Q462



Red Hill Tank 4

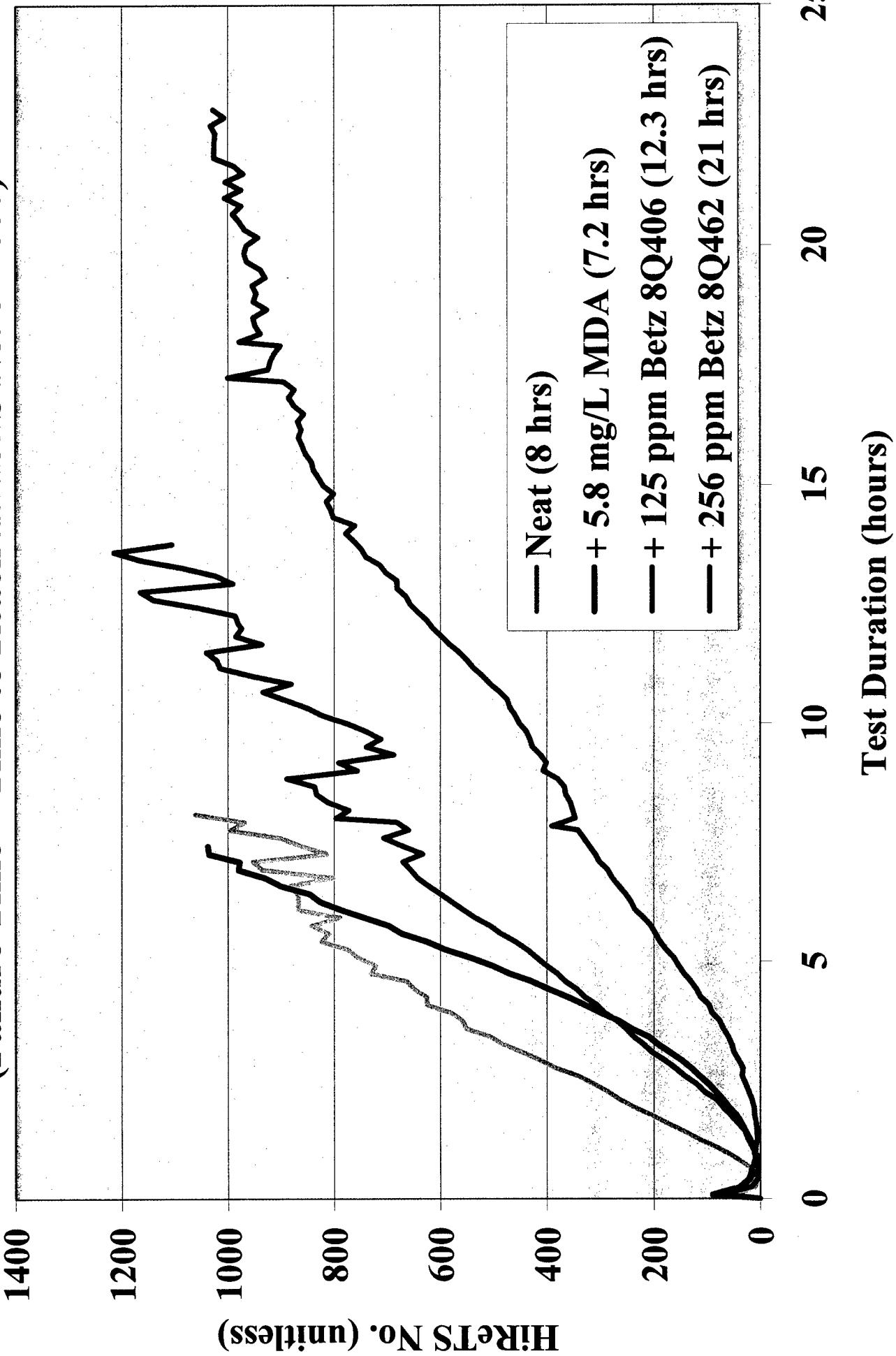
Tank 17/19

Tank 20/22

HiReTS Data

Red Hill Tank 4 (BPT = 255°C)

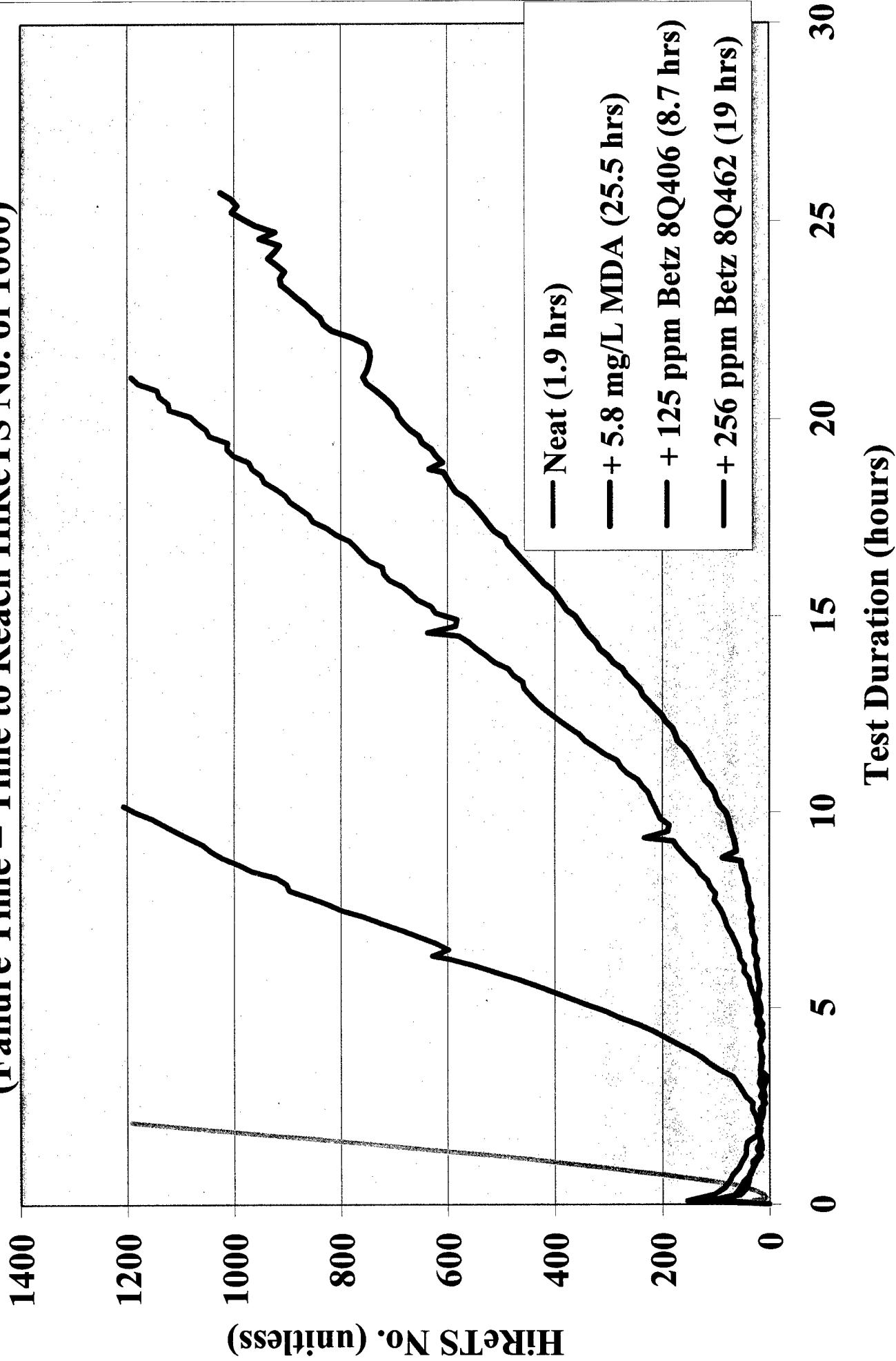
(Failure Time = Time to Reach HiReTS No. of 1000)



HiReTS Data

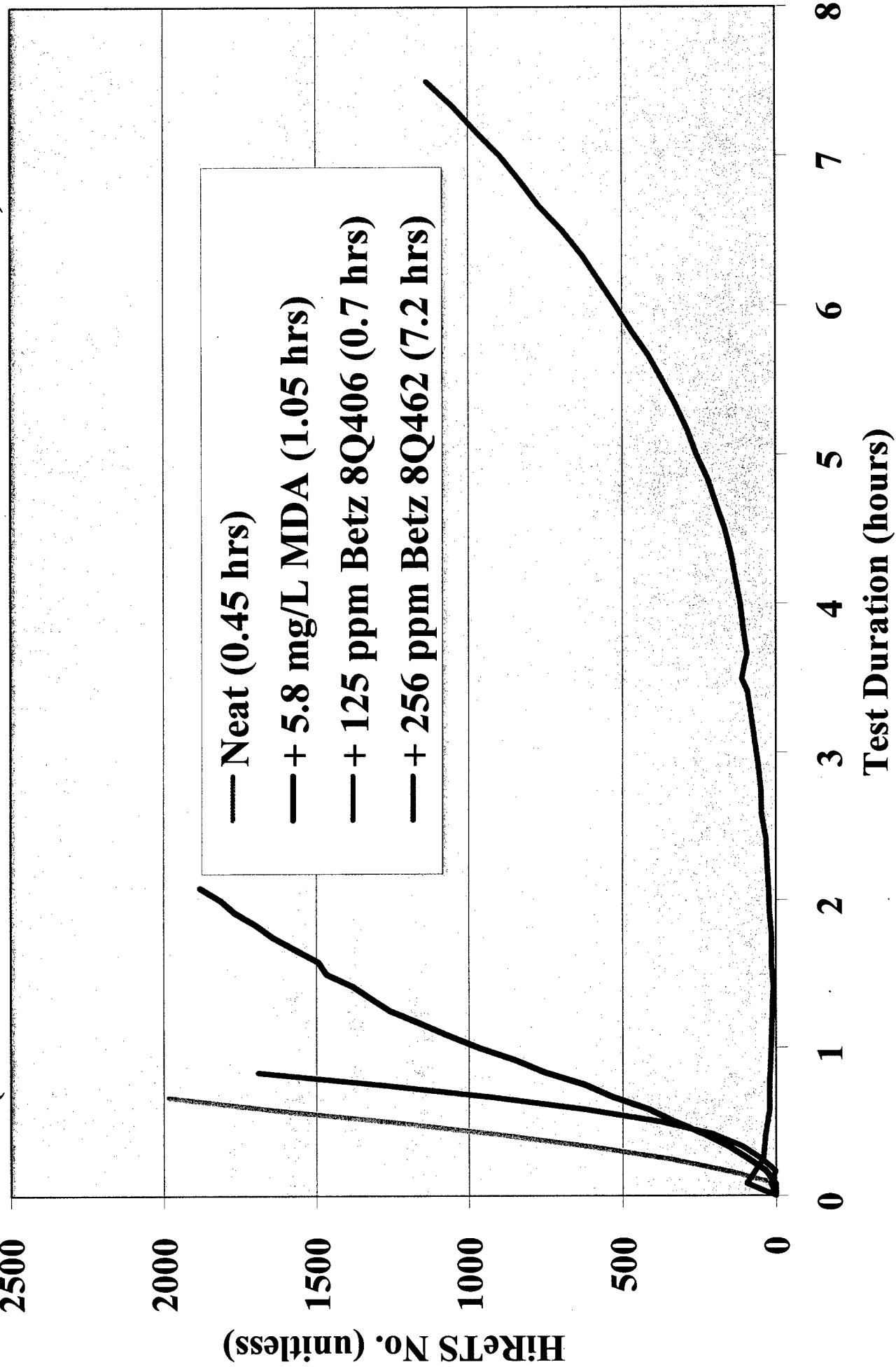
Tank 17/19 (BPT = 272°C)

(Failure Time = Time to Reach HiReTS No. of 1000)



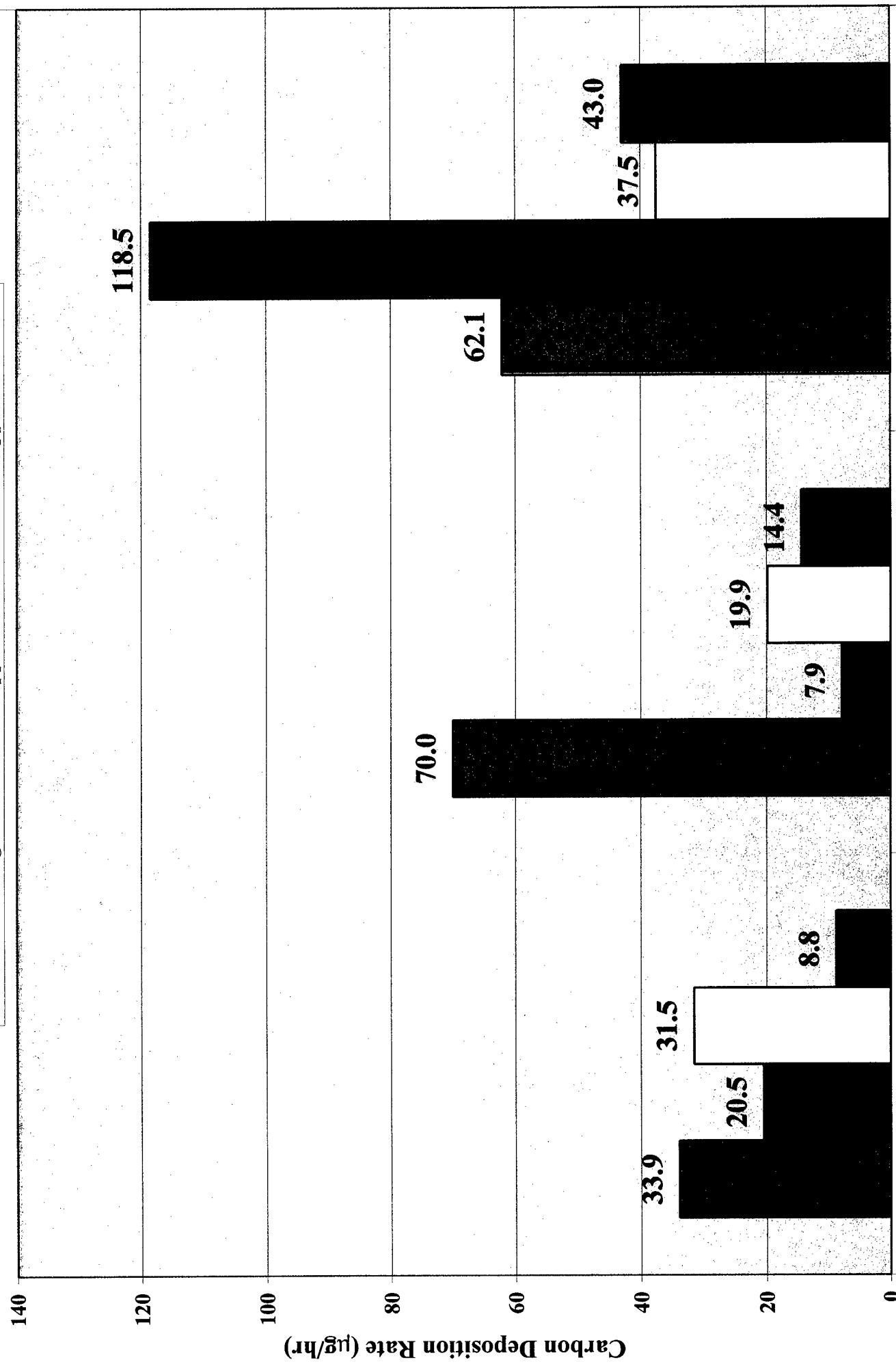
HiReTS Data

Tank 20/22 (BPT = 265°C) - Contains 50 ppb Cu
(Failure Time = Time to Reach HiReTS No. of 1000)



HiReTS Capillary Carbon Deposition

■ Neat ■ + 5.8 mg/L MDA □ + 125 ppm Betz 8Q406 ■ + 256 ppm Betz 8Q462



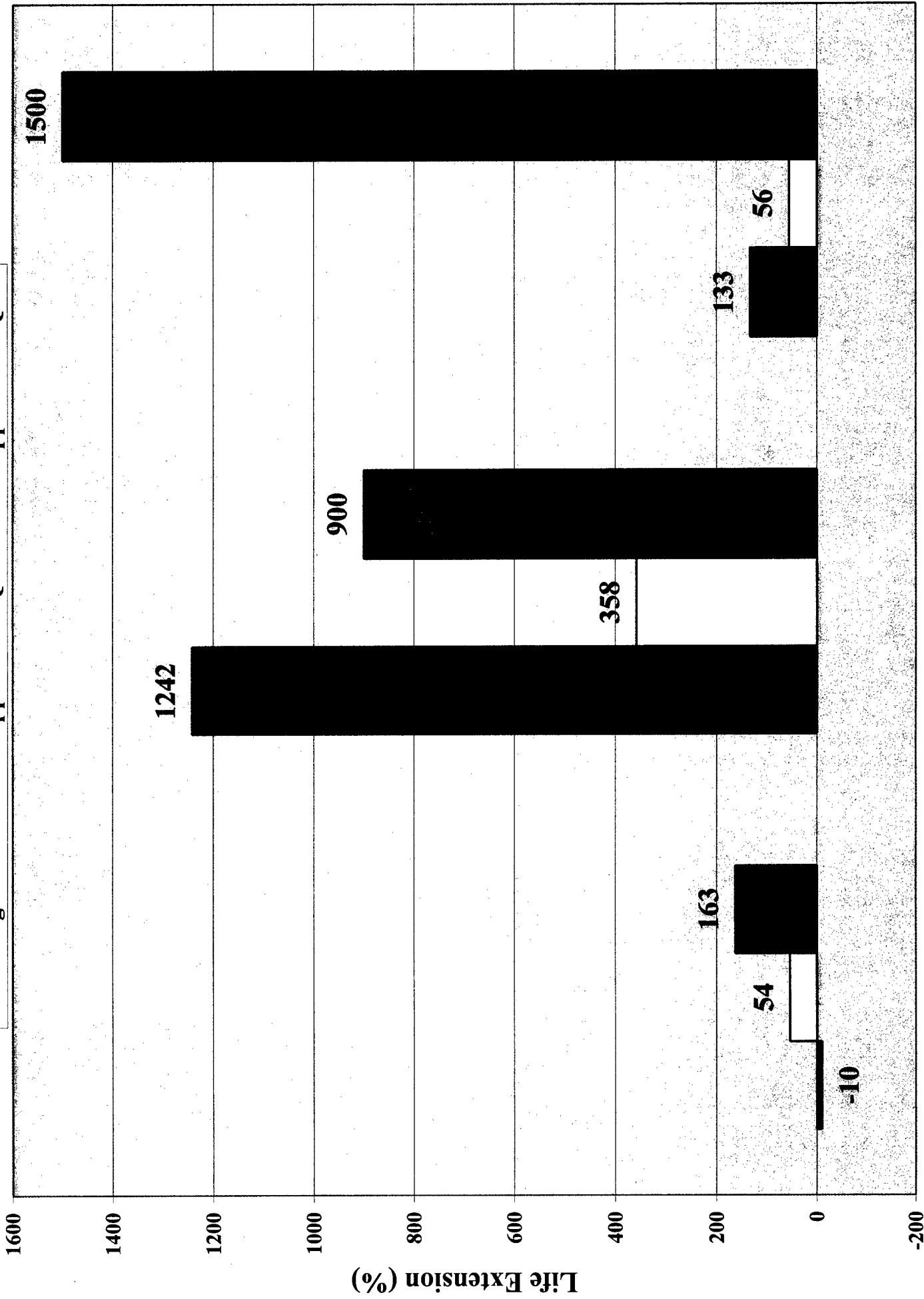
Red Hill Tank 4

Tank 17/19

Tank 20/22

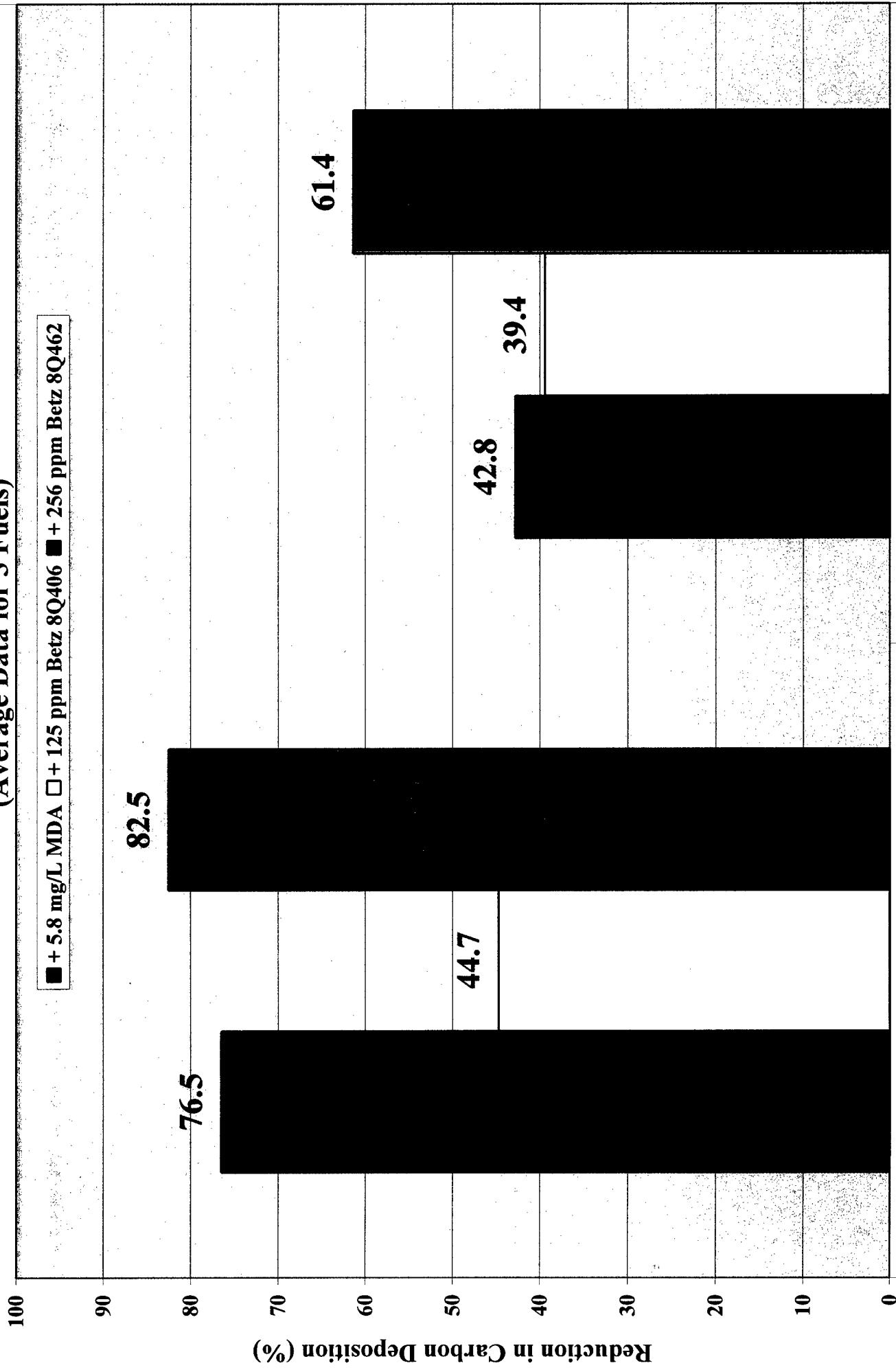
HiReTS Capillary - % Life Extension

■ + 5.8 mg/L MDA □ + 125 ppm Betz 8Q406 ■ + 256 ppm Betz 8Q462



Summary of Results

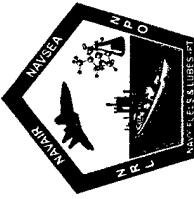
% Reduction in Surface Deposition (Average Data for 3 Fuels)



Laminar

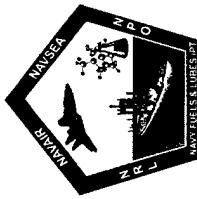
Turbulent

CONCLUSIONS



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- All three (3) TSAs reduce the amount of thermal deposits, measured via carbon burnoff, in both laminar and turbulent test units for the three (3) different base fuels tested.
- For the laminar test unit, Betz 8Q462 shows better deposit inhibition than MDA by a narrow margin.
- Therefore, MDA shows a synergistic effect when added to the Betz 8Q406 (to produce Betz 8Q462) in the laminar unit.



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CONCLUSIONS (Cont.)

- The turbulent unit is sensitive to differences in fuel chemistry, possibly due to the higher operating temperatures and/or the HiReTS capillary dimensions (viz., inside diameter).
- The higher operating temperatures of the turbulent unit may be unrealistic (i.e., too severe) for evaluating additives.
- Nevertheless, Betz 8Q462 appeared to be the most effective additive overall in the HiReTS.



RECOMMENDATIONS

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- For research purposes, the following modifications should be considered to make the HiReTS better-suited for evaluating fuels and additives:
 - Incorporate a pre-heater
 - Operate at a lower capillary exit temperature
 - Run the test for an extended duration until a capillary failure condition is achieved while minimizing the test duration and fuel consumption



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RECOMMENDATIONS (Cont.)

- For the HiReTS, scan a larger length of the capillary to include SEC 2 and SEC 3 to get a better indication of true deposition rate.
- Use the HiReTS No. as an indication of deposit level and/or rate. Also, reduce the test duration until a HiReTS No. of 500 is achieved and measure the associated deposition rate.